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THE  
AMERICAN NATURALIST

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VOL. XXX.

April, 1896.

352

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THE BEARING OF THE ORIGIN AND DIFFERENTI-  
ATION OF THE SEX CELLS IN CYMATOGASTER  
ON THE IDEA OF THE CONTINUITY OF  
THE GERM PLASM.<sup>1</sup>

CARL H. EIGENMANN.

At the meeting of the American Microscopical Society last August I read a paper on the Evolution of Sex in *Cymatogaster*, of which the present paper is a part. It is not, and was not intended as a full discussion of heredity, but contains observations and conclusions forced upon me while tracing the sex cells from one generation to the next in *Cymatogaster aggregatus* Gibbons, one of the viviparous perches of California.

Since writing it, I have received from Dr. Minot his article "Ueber die Vererbung und Verjüngung," which is just being republished in the NATURALIST. I have thought best to present my results as read at the Ithaca meeting, with a note written after the receipt of Dr. Minot's article, although the details of the observations on which the conclusions are based may not appear for some time.

<sup>1</sup> Contributions from the Zoological Laboratory of the Indiana University, No. 12.

The origin of the heredity cells may be explained in one of three ways:<sup>2</sup>

I. The sex cell is the product of the whole organism, and is in this apart from the other tissues. This is the *Pangenes* of Darwin.

II. The sex cell is an unchanged but increased part of the sex cell of the previous generation, and something apart from the rest of the body. This is *Jaegerism*, or, more popularly, *Weismannism*, and, according to it, the body has no influence over the hereditary cells and changes arising during the life of one individual cannot be transmitted to the next generation.

III. The sex cell is the product of histogenesis and of precisely the same significance and origin as any other cell in the body. This view is held by Morgan, Minot and myself.

As a corollary of the last two is the fact that "in the ancestry of the individual cells of which our body is composed there has never been a death."

The first two theories are not based on observation. They have been evolved from the attempts to explain the heredity power of the sex cells.

The idea of the cellular continuity of successive generations first suggested by Nussbaum in 1880, is now generally accepted. Indeed, there is, perhaps, now no one who would contend that the reproductive cells are new formations in the individual. The reproductive cells are known to be of the same origin as the retinal or any other series of cells. There is but little less unanimity over the idea of the continuity of the unchanged germ plasm, although the number of observations bearing on this point have, necessarily, been very limited.<sup>3</sup> So often is the idea restated without actual examination of the data, the whole subject has become hackneyed. I have taken up this subject because it seems to me the conditions observed in *Cyrtogaster* warrant a conclusion differing from the one generally accepted.

<sup>2</sup> See Osborn, *Am. Nat.*, 1892. Morgan, *Animal Life and Intelligence*, 1891, p. 131.

<sup>3</sup> Boveri, *Befruchtung in Ergebnisse der Anatomie und Entwicklungsgesch.*, I, 1892, records an apparent case of unchanged transmission.

There is no doubt concerning the continuity of the reproductive cells in *Cymatogaster*; they may be followed from very early conditions till sexual maturity without once losing their identity. No somatic cells are transformed into reproductive cells, and the comparative constancy of the number of the latter present in any embryo up to 7 mm. long makes it probable that none<sup>4</sup> are ever changed into any other structure. These statements apply with equal force to other tissues.

The difference between the reproductive and the somatic cells is that the latter, after development has begun, continue to develop, divide, grow and adapt themselves to their new duties without intermission. The sex cells, on the other hand, stop dividing at a certain point and remain at apparent rest for a long period. Owing to this arrest in division the sex cells soon stand out prominently as large cells among the smaller somatic cells. Such an arrest in segmentation has been observed in a number of other animals in which the reproductive cells are early segregated, and it cannot be without meaning. It has been supposed that during such periods of apparent rest the cells remain dormant, retaining their embryonic character unchanged. I do not think this is the true reason for the difference of development between the soma and the reproductive cells. The reason seems to me to lie in the fact that the sexual organs are the last to become functional, and their development is consequently retarded. The sex cells, when first segregated—that is, when they first lag behind in segmentation—are not exactly like the ovum from which they have been derived, and there is just as true histogenesis in their development into the reproductive tissues as in the case of any other embryonic cells into their corresponding tissue. Even during the long period of rest from segmentation, the process of tissue differentiation produces a visible and measurable change. But the difference between embryonic cells and undifferentiated reproductive cells being small, the histogenic changes in them during early stages is correspondingly small. This small change has been supposed to amount to no change, and has given rise to that fascinating “myth”, the

<sup>4</sup> For possible exceptions see Eigenmann, *Journ. Morph.*, V, No. 3, 1891.

hypothesis of the continuity of unchanged germ cells, and later, when observation in other animals had made this theory untenable, to the theory of the continuity of unchanged germ plasm which is beyond the ken of direct observation.

If the sex cells are the result of histogenesis, it will be necessary to explain their peculiar power. They seem to me to be due to the same processes that have given the retinal cells their peculiar properties.

Assimilation, reproduction and the closely allied hereditary power are the diagnostic characters of protoplasm. These, with numerous other powers, such as contractility, conductivity and irritability, are the properties of every protozoan cell. Even here we find that certain of these functions are more or less restricted to definite parts of the cell. In the higher animals this differentiation has gone so far that definite functions predominate in highly specialized cells to almost the exclusion of the other powers.

With this division of labor and the consequent histogenic differentiation of definite cells in the metazoan corm for purposes of contraction, conduction and irritation, we have also the differentiation for heredity, and it would be surprising if we did not.

In lower forms, where the cells of the body often perform many duties, where the division of labor and histogenesis has not been carried to the extreme, many of these cells also retain the hereditary power to a great extent as shown in the power of budding or regeneration.

There seems to be no necessity to conjure up a substance and processes in the genesis of the reproductive tissues different from those obtaining in the muscular tissues.

During the long ages of the rise of animals those possessing sufficiently differentiated contractile tissue to move the corm to food or from danger have survived, and in precisely the same way those corms containing cells capable of developing into other similar corms have survived. Similar causes have operated in producing each tissue.

The sex cells are proven to influence the formation of the sex ridge. The peritoneal cells rise to form the ridge only

when sex cells are present without regard to whether this position is normal or not.<sup>5</sup> If the sex cells thus influence the surrounding tissue, may we not safely assume a reciprocal influence of the surrounding tissues on the reproductive cells?

Sexuality can first be distinguished not by the difference in the sex cells, but by the character of the peritoneal covering. While this difference in the peritoneal covering may be the expression of an invisible difference existing in the reproductive cells, it is quite possible that sex is determined by the body. In frogs, butterflies, etc. the sex determining power of the soma has been experimentally demonstrated. Later it is well known that the character of the sex cells influences the remotest parts of the organism, although we are not at all familiar with the processes by which this is accomplished.

Changes in the sex cells introduced by the body which do not become apparent until the development of the cells into young, seem, therefore, to be not impossible, although we are entirely unable to tell just how such a change might be accomplished.

Since writing the above, I have received, through the kindness of the author, Dr. Minot's "Ueber die Vererbung und Verjüngung." While the views expressed are not identical with those given in the present chapter, there is considerable agreement. Dr. Minot recognizes that the problem of the origin of the reproductive cells is also the problem of the origin of the tissue cells (p. 580), and that "a germ plasm in the Weismannian sense does not exist." So far we agree. According to him all parts inherit from the germ and possess, as well as the reproductive cells, the power of multiplying and morphogenesis, but this power cannot manifest itself on the part of the somatic cells because the conditions of the body prevent it. The conditions are the increased amount of protoplasm and the specialization of the tissues. According to my views it is not so much a high state of tissue differentiation which *holds captive* the morphogenic power in muscle cells for instance as it

<sup>5</sup> In one interesting larva a few of the sex cells were belated in their migration and situated in front of the normal position. Sex ridges (germinal bands) formed about these sex cells entirely independent of and separated from the sex ridges occurring in the normal place.

is the process of tissue differentiation which *emphasizes* the contractile power in the muscle cell, at the same time *limiting* and finally *eliminating* the morphogenic power, and which gives the sex cells morphogenic power in such marked degree while it deprives them largely of contractile power. In a former paper,<sup>6</sup> I stated this view thus: "The segmentation nucleus of metazoa contains, as in the infusoria, both micro and macro nuclear elements, but these are retained in varying proportions in its descendants, *i. e.*, in the cells of the adult organism. Through a process of division of labor the power of rejuvenescence becomes restricted to comparatively few of the cells derived from the segmentation nucleus."

While Minot's views are in part borne out by the conditions in Cymatogaster, the italicised part of the quotation below finds no support, and is negatived by all the observations made in Cymatogaster. His conclusion, as translated by me, is: "Somatic cells are simply cells in which the activity of heredity is prevented by senescence, *viz.*: tissue differentiation, *but the somatic cells can, under favorable conditions, be translated into the rejuvenated stage and then develop the most complete or, at least, more complete, hereditary power.*"

ABSTRACT OF OBSERVATIONS ON WHICH THE ABOVE CON-  
CLUSIONS ARE BASED.

The sex cells originally segregated retain their individuality, but undergo a measureable change between the time of their segregation and 7 mm. long larvæ. Soon after the larva has reached a length of 7 mm., the sex cells begin to divide. In the meanwhile they have migrated laterad and lie, for the most part, in a longitudinal groove formed by a duplication of the peritoneum into which a few peritoneal cells have also migrated. *In one such case an extra sex ridge was formed much further forward than usual, in connection with a few sex cells which were accidentally belated in their migration.* The peritoneal cells which have migrated into the sex ridge give rise to the entire stroma of the future sex glands, and together with the sex cells form a core quite distinct from the covering

<sup>6</sup> Bull. U. S. Fish Comm., XII, 442, 1894.

of peritoneum. Posteriorly the sex ridges of the two sides are united into a single ridge. There is considerable variation in the rate of segmentation in larvæ of the same size, but the following table will give an idea of the segmentation and the number of cells in successive stages :

Size of larva.	No. of sex cells.	No. of generations from fertilization.
45-5 mm.	9-15	5
8	22	6
10	28-183	6-9
12	39-143	7-9
15-17	638-2280	11-13 sexes distinct.
16-25	2200-8000	13-15

The sexes can first be distinguished not by the differences in the sex cells, but in the tunic of peritoneal cells. A small groove on the outer ventral part of the sex ridge is the first indication of the ovarian cavity and the surest criterion of the female. In the male the sex gland remains much more circular in cross section and no groove is developed. Much later histological differences in the sex cells themselves can be made out. The long slender chromatin threads of the female cell just before dividing are represented in the male by short, thick bars.

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## THE HISTORY AND PRINCIPLES OF GEOLOGY, AND ITS AIM.

BY J. C. HARTZELL, JR., M. S.

(*Continued from page 183.*)

Lamarck and Defrance earnestly engaged in study of fossil shells, and the former, in 1802, reconstructed the system of conchology and introduced into it the new species collected by the latter from the strata underlying the city of Paris and quarried for the construction of its buildings. Six years previous to this Cuvier had established the different specific character of fossil and living elephants and he devoted himself to researches throughout the remainder of his life. Jameson, in 1808, pointed out the nature of all the rocks and the mode in which they were formed, and made use of the observations